UNIT 1 - ENERGY
SECTION 3 - ENERGY SOURCES

Vocabulary

active solar collection
alternative energy
biomass
conventional energy
dam
electric vehicle
electricity
energy source
fetch
geothermal
geyser
gradient zone
grid
hybrid vehicle
hydroelectric
hydropower
maglev
non-fuel energy source
passive solar
penstock
photovoltaic cell
primary energy source
resources
secondary energy source
solar collector
solar pond
solar reflector
storage zone
surface zone
tidal dam
tide
transformer
turbine
volt
voltage

Energy Sources

An **energy source** is a supply of energy available for use. Energy sources are sometimes referred to as **resources**. This section will discuss primary, secondary and alternative energy sources.

All energy sources are available for humans to use, but not all are practical or economic. For instance, we do not regard stars other than the sun as practical energy sources, because they are so far away.

Some energy sources are easy to use anywhere, such as the sunlight that allows us to see well during the day. Other energy sources work only in certain places. For example, waves and tides can be used as energy sources only near coastlines.

Examples of energy sources available for use today include:

Form of energy	Energy source	Example of application
mechanical	wind	windmill that pumps water
thermal	hot spring	providing hot water to swimming pool
radiant	sunlight	growing food plants
nuclear	atomic nucleus	reactor produces thermal energy used to generate electricity
chemical	natural gas	burning to warm a house

Figure 1-3-1 Examples of energy sources

Figure 1-3-2 Propane-powered grill
Propane, a storehouse of chemical energy, is burned to release thermal energy to cook food.

Primary Energy Sources

Primary energy sources are sources that are naturally available on the earth. Primary energy sources can be renewable or non-renewable.

Renewable energy sources are reoccurring or continuous. The sun is the main source of renewable energy. Other renewable energy sources include **geothermal, hydropower**, wind, and **biomass**.

Non-renewable sources take a long time to form and cannot be replenished during a human lifetime. Examples are fossil fuels such as coal, oil, natural gas and propane.

An example of a primary energy source that is renewable is hydropower. A water wheel placed in a flowing stream converts the kinetic energy of the moving water and uses it for human benefit, for example, to turn a millstone that grinds grain or to turn a turbine to produce electricity.

An example of a primary energy source that is non-renewable is the propane gas in a barbecue grill (figure 1-3-2). The grill releases chemical energy stored in the fuel as thermal (heat) energy to cook food.

Non-Fuel Energy Sources

Non-fuel energy sources yield energy from a source other than direct combustion.

Geothermal

Geothermal energy is heat generated by radioactive decay in the earth's core thousands of miles beneath the planet's surface.

In a few places, this hot layer beneath the earth's crust comes close enough to the surface to erupt, spilling hot magma onto the earth's surface, or to heat underground water and force it to the surface as geysers or hot springs.

Deep wells can tap pockets of superheated water in the form of steam. The steam's energy may be used directly or to turn a **turbine** to produce electricity.

The first geothermal power plants in the U.S. were built in 1962 at The Geysers dry steam field in northern California. This is the largest geothermal power-producing plant in the world. The use of geothermal energy has grown in the U.S. over the last three decades (figure 1-3-4). Geothermal power plants currently supply more than 2.8 gigawatts of electricity to about 4 million people in the U.S. Worldwide electrical production from geothermal energy is equivalent to that produced by six nuclear power plants.

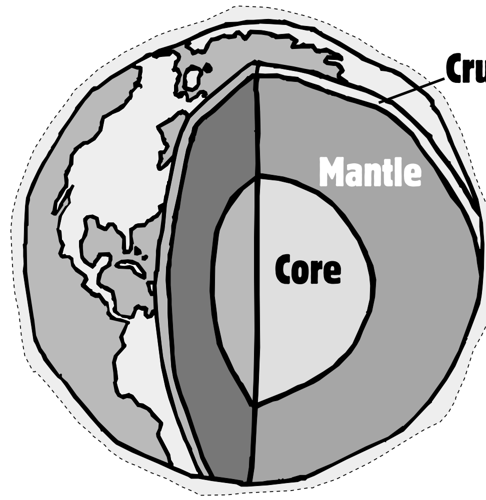


Figure 1-3-3 Layers of the earth
Geothermal energy comes from heat in the earth's core.

Geothermal power plants are restricted to locations where the earth's internal thermal energy is close to the surface. However, geothermal heat pumps can be used effectively over a wide range of earth temperatures. Geothermal heat pumps move energy in both directions. In summer, heat can be transferred from a building into the earth, cooling the building. In winter, the process is reversed.

Geothermal energy is used for:

- **Recreation** – *hot springs and spa bathing such as Stacy Pool in Austin, Texas*
- **Agriculture** – *greenhouse and soil warming*
- **Aquaculture** – *fish, prawn, and alligator farming*
- **Industrial uses** – *product drying and warming.*

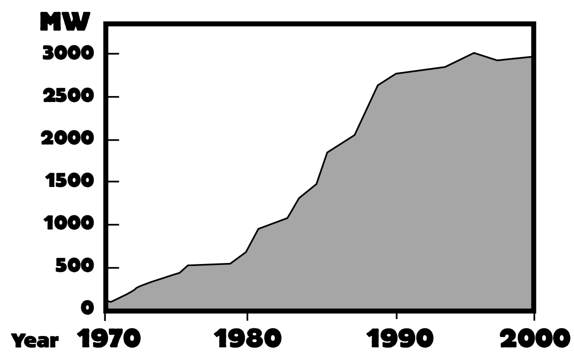


Figure 1-3-4
Growth of U.S. Geothermal Power

Well, Well!

Early settlers in Marlin, Texas, drilled a 3,000-foot well looking for water. A 50-ft. **geyser** of hot water erupted into the air. By the 1960's Marlin had become one of the world's leading health resorts. Although Marlin is no longer a major health resort, the Falls County Community Hospital and clinic still uses the water for geothermal heating.

Hydropower

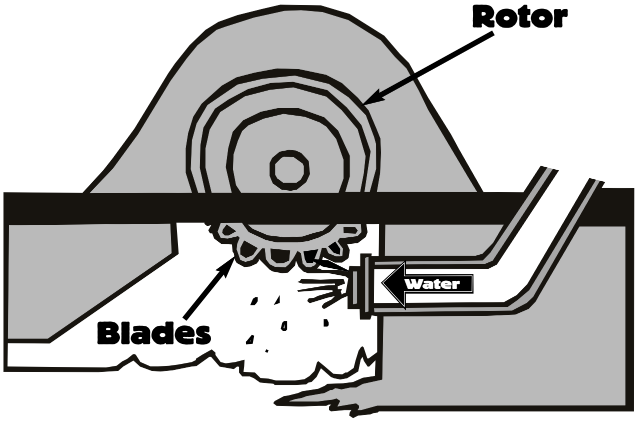


Figure 1-3-5 What is a turbine? *A turbine uses a rotor, a circle of curved blades, to get the most power from flowing water or fast-moving steam. In the water turbine above, water is forced directly against the blades of the rotor, causing it to turn. The rotor then turns an electric generator.*

Hydropower refers to converting the gravitational potential energy resulting from differences in elevation of water and the kinetic energy contained in moving water into electricity. Hydropower usually refers to power derived from the potential energy of water released from behind a dam on a river to a lower elevation. But it can also refer to alternative types of water energy, such as tide power and wave power.

The first use of moving water to produce electricity was a waterwheel on the Fox River in Wisconsin in 1882, two years after Thomas Edison invented the incandescent light bulb. Shortly thereafter, the first of many U.S. hydroelectric power plants was completed in Niagara Falls, New York.

Dams

A **dam** is a barrier that stores water at a high elevation. **Hydroelectric** plants use dams to channel high velocity water. Water passing over or through the dam turns the blades of a turbine. As the turbines rotate, they generate electrical power.

There are three types of dams: impoundment, diversion, and pumped storage. Impoundment dams store water in a lake behind the dam. The stored water may be released to a lower elevation to generate electricity or maintain water levels. Diversion dams generate electricity by channeling all or part of a river through a canal or **penstock** that directs the water past the blades of a turbine. Pumped-storage dams pump water from a lower reservoir to a higher elevation reservoir and then release the water back into the lower reservoir to generate electricity.

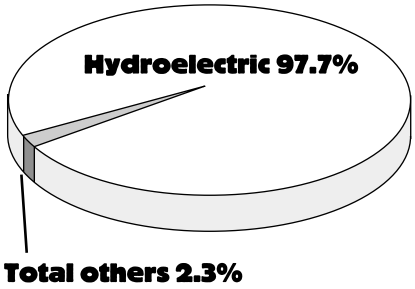


Figure 1-3-6 Generation of electricity by renewables 1998.

Hydropower from dams accounts for 98 percent of the renewable electric energy in the United States (figure 1-3-6) and produces 10 percent of U.S. electricity. The U.S. and Canada are the top hydroelectric generating countries in the world.

The untapped potential from new and existing dam sites has been studied by the U.S. Department of Energy and the Idaho National Engineering Laboratory. These organizations have identified 89 sites within 8 river basins in Texas as having hydropower potential (figure 1-3-7).

Environmentally speaking, dams pollute the air less than fossil-fuel power plants and create more manageable wastes than nuclear power plants. However, damming rivers and flooding large areas does substantially affect local habitats and human populations.

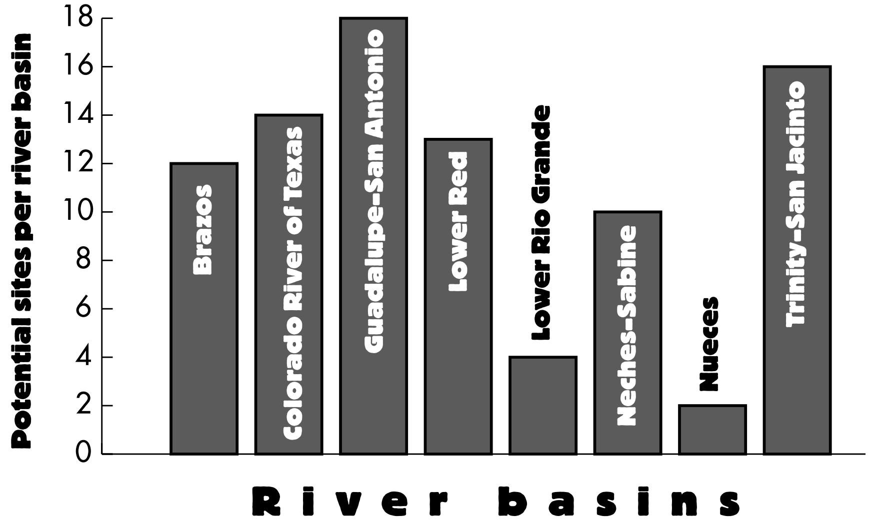


Figure 1-3-7 Number of sites with potential hydropower capacity in Texas river basins

Tides

Tides are the regular rise and fall of the ocean level due to the gravitational pull of the moon on the earth. As the moon moves in its orbit around the earth, the ocean bulges on the side of the earth facing the moon, raising sea level relative to inland bays and estuaries. This bulge is high tide. At high tide, seawater flows inland into coastal bays and estuaries (figure 1-3-8). At low tide, as the ocean level falls, this water ebbs back out to sea.

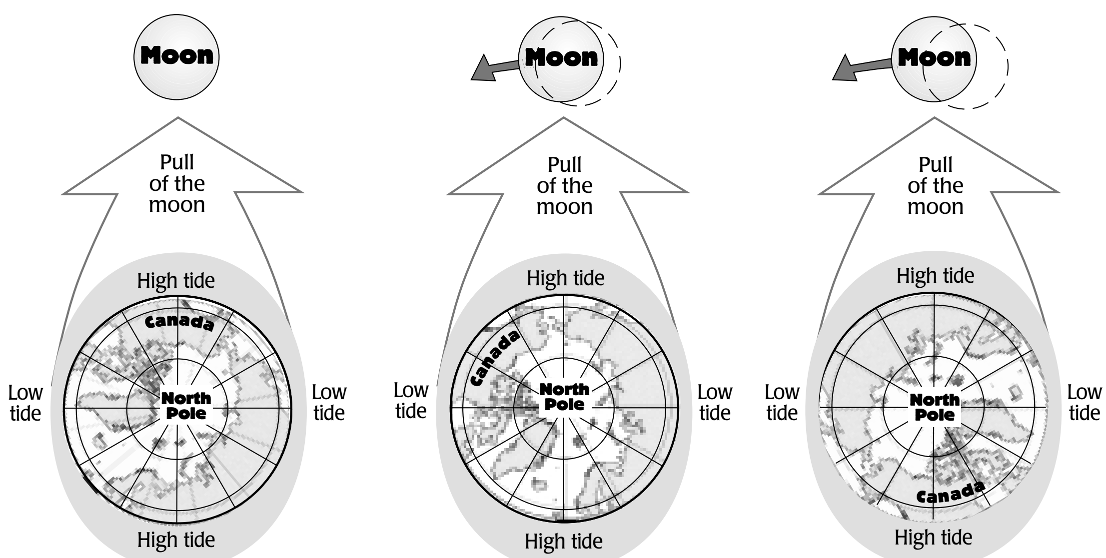


Figure 1-3-8 *The pull of the moon's gravity causes high tides in two places: directly below the moon and on the opposite side of the earth.*

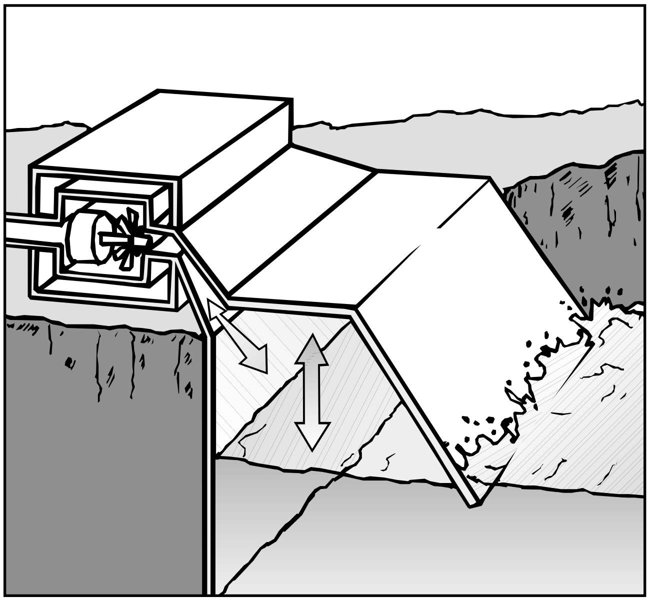


Figure 1-3-9 New wave power *Waves are funneled into a rock gully. The constant rise and fall of the water forces air through a turbine that drives a generator. When tests are complete, the device could supply electricity to small, isolated coastal communities.*

The idea of capturing the energy of tides dates back to eleventh century England when tides were used to turn waterwheels. Currently, tides are used to generate electricity on a small scale in several countries. A big tidal generating station is located on the La Rance estuary in France.

Energy generated from tides is similar to energy generated by damming a river. A **tidal dam** is built across a bay or estuary. When the tide rises or falls, a gate is opened, causing water to flow through a turbine that is connected to an electric generator. Electricity can be generated by water flowing both into and out of a bay.

The energy-producing potential of a tidal dam depends on the difference in ocean level between high and low tides. The greater the difference, the more electricity that can be produced. The Bay of Fundy in Atlantic Canada, with a difference of 17 meters (55 feet), has the highest tides in the world. To be practical for electricity generation, the difference between high and low tides must be a least 15 feet.

Tidal dams have the potential to supply significant amounts of electricity. Studies show the environmental impact to aquatic and shoreline ecosystems and the atmosphere to be minimal. The major drawback is the high initial cost of building the facility.

Waves

Winds blowing across the surface of the world's oceans transfer massive amounts of kinetic energy to the water. This energy is visible as waves. The total amount of power released by waves breaking along the world's coastlines has been estimated at 2 to 3 million megawatts, equivalent to the output of 3,000 large conventional power plants.

Wave size depends on wind speed and **fetch**, which means the distance over the ocean's surface that the wind travels. Favorable wave-energy sites are generally western coastlines facing an open ocean, such as those in North America and northern Europe. Norway, Denmark, Japan and the United Kingdom are the world leaders in wave-energy technologies.

Three types of wave-energy systems have been developed to produce electricity:

- surface floats
- oscillating water columns
- focusing devices

Surface floats connect one or two floating devices to a fixed object. Waves hitting the surface floats produce mechanical power, which drives a turbine generator. Waves hitting an oscillating water column compress the air inside and force it past air turbines. Focusing devices are barriers that channel waves into a small area, causing them to increase in height. The water is then captured in a reservoir and directed to flow over hydroelectric turbines as it is released to return to the ocean at a lower elevation.

Two-thirds of the earth is covered by water. The oceans of the world could potentially provide a limitless supply of renewable energy. The technology to harness wave power is still in its infancy, and its environmental impacts are not yet fully understood.

Solar

A **solar collector** is a device that converts solar energy into thermal energy. Solar collectors can be active or passive. Passive solar collection means designing a home or building to take advantage of the sun's energy to heat a house, such as floor-to-ceiling windows that face south. **Active solar collection** requires special equipment and technology to harness the sun's energy. Active solar collectors include **solar ponds, solar reflectors** and **photovoltaic cells**.

Solar Ponds

Liquids and gases such as water and air rise when heated. This natural process can be harnessed to store thermal energy in a solar pond. Solar ponds stop the natural process of mixing by using another natural resource: salt.

Solar ponds are large, shallow, human-made bodies of water lined with dark material. The pond has three main water layers: the **surface zone**, the **gradient zone**, and the **storage zone**

(figure 1-3-10) which is very salty. The gradient zone separates the surface zone and the storage zone. The salt content in the gradient zone increases with depth. Water in the gradient zone can't rise because the water above it contains less salt and therefore is less dense. Similarly, the cool water can't sink because the water below it has a higher salt content and is denser. Hot water in the storage zone is piped to a boiler where it is heated further to produce steam, which drives a turbine.

The University of Texas at El Paso started the El Paso Solar Pond project in 1983. Since May 1986 the El Paso Solar Pond has produced hot water, electricity, and fresh water. Thermal energy drawn from the bottom layer is used to preheat boiler water for a local canning operation. In October 1986 the El Paso Project became the United States' first solar pond to generate electricity, producing up to 70 kW. Even at night or after long periods of cloudy weather, the solar pond has been able to deliver power on demand.

Solar ponds have several important advantages. They can be built easily and at a relatively low cost over large areas, using and storing solar energy on a grand scale. They can't pollute the air, and coupled with desalting units, they can be used to purify water.

Solar ponds are of great interest in desert countries such as Israel, where research into this technology has been going on for decades. The ponds provide power for otherwise

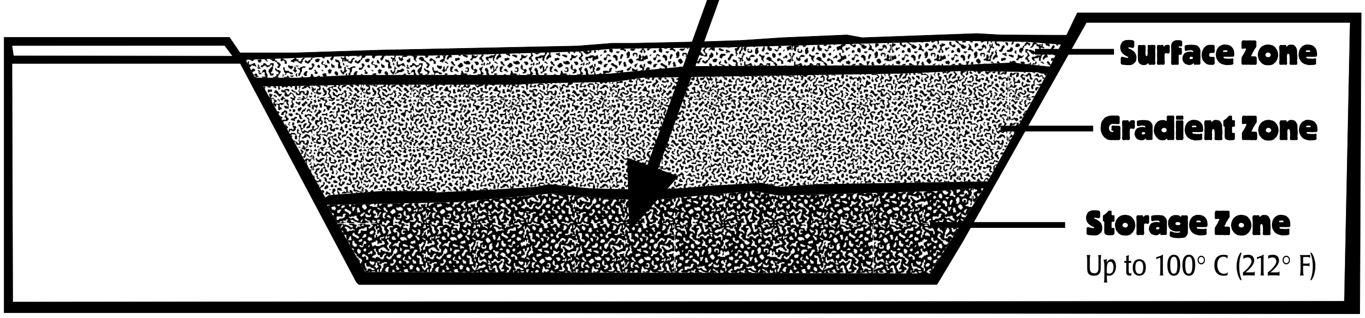


Figure 1-3-10
Layers of a solar pond

unproductive land, and they can provide fresh water as a by-product with the addition of a low temperature desalting unit.

Solar Reflectors

Solar thermal systems use mirrored surfaces to concentrate sunlight onto a receiver that superheats a liquid. The liquid turns to steam, which spins a turbine.

There are three common types of solar reflectors: parabolic troughs, parabolic dishes, and power towers.

A parabola is a geometric shape that focuses all incoming light on one focal point. Parabolic troughs and dishes use parabolic shaped mirrors to focus incoming radiant energy onto a receiver, which is located at the focal point in the center of the dish. Fluid in the receiver is heated to about 750^{o}C. This superheated fluid is then used to generate steam that turns a turbine to generate electricity.

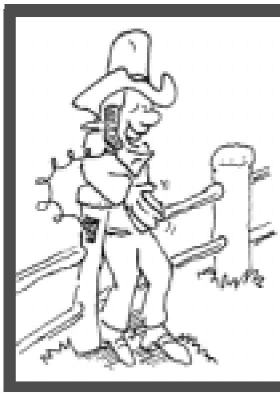
Power towers use large flat mirrors to focus sunlight onto a receiver located on a tower. The receiver contains fluid or molten salt, which is heated to generate steam, which is used to turn a turbine at the foot of the tower to generate electricity.

Two power towers called Solar One and Solar Two in Barstow, California, produce utility-scale power from sunlight (up to 10 megawatts). Solar Two uses 2,000 mirrors to focus solar radiation on molten salt. This energy is then used to generate electricity when needed.

Photovoltaic Cells

The word photovoltaic comes from “photo,” meaning light, and “voltaic,” referring to producing electricity. A photovoltaic cell is a device that produces electricity directly from sunlight.

Photovoltaic cells are made of at least two layers of semiconducting material. The first layer has a positive charge; the next layer has a negative charge. When sunlight strikes the cell, the semiconducting material absorbs the photons from the light. This process frees electrons from the negative layer, which move to the positive layer. This flow of electrons produces an electric current. The electricity generated by a photovoltaic cell can be used directly, stored in batteries or sold back to a utility company.



On the fence

Electric fences were first used on a Texas ranch in 1888. Today solar-powered fences are used extensively in the Texas Panhandle to fence cattle in. The idea of the electric fence was to reduce the need for fence posts, injure cattle less than traditional barbed wire, and allow cowboys riding the fence line to tap into a telephone attached to the electric fence.

Since the 1950's, photovoltaic power has been a source of energy for the U.S. space program. The National Aeronautics and Space Administration uses photovoltaic cells to power satellites, space probes and the International Space Station. According to NASA, future possibilities include powering base camps on the moon and building solar photovoltaic collectors in space to convert radiant energy to electricity and beam it down to earth.

Passive Solar

In a passive solar house, the building's site, orientation, design, and materials take advantage of the natural warming power of the sun.

Using the sun as a heat source is nothing new. Twenty-four hundred years ago, Socrates observed:

> Now in houses with a south aspect, the sun's rays penetrate into the porticos in winter, but in the summer the path of the sun is right over our heads and above the roof, so that there is shade. If then this is the best arrangement, we should build the south side loftier to get the winter sun and the north side lower to keep out the winter winds.
>
> *- Xenophon, Memorabilia of Socrates VIII. 14*


© Cliff Wassmann

Figure 1-3-11
Anasazi Indian homes

Later, the Romans discovered that if a south-facing portico and windows were covered with glass, the energy of the sun would be trapped, causing the building to stay warm into the night.

Pre-Columbian Native American architecture also shows an understanding of passive solar energy. Cliff dwellings made of earth faced south, welcoming the winter sun yet providing protection from direct overhead rays in the summer.

Rammed-earth solar homes use passive solar principles today. Rammed-earth walls 18 to 24 inches thick are created by forming a mixture of cement, water and earth. This mixture is poured into a form. When the mixture has dried, the form is removed. Rammed-earth walls have a high thermal mass, or the ability to store thermal energy. When the sun's rays enter a room, their heat penetrates and is stored in the walls. This stored radiant energy is then available to help balance any drop in room temperature during the night.

Wind

We are familiar with images of Dutch windmills and the lonely skeletons of windmills in the American West. Today, most windmills are built to generate electricity instead of grinding grain or pumping water.

Windmills transfer the kinetic energy of the wind to the blades. The blades, ideally about 60 feet long, are connected to a shaft that turns the shaft of an electric generator.

Today, in north and west Texas, wind power plants generate 187 megawatts of power, with a potential 731 additional megawatts proposed or under construction. Texas is second only to North Dakota in wind energy in the U.S. The largest wind farm in Texas, consisting of 107 wind turbines, is located 350 miles southwest of Dallas, atop a 2000-foot mesa. This wind farm generates enough electricity to power more than 20,000 households.

Figure 1-3-12 *On wind "farms," hundreds of windmills can generate large amounts of electricity. It is estimated that Texas has the potential to generate 10 percent of the entire country's energy requirements through wind power.*

Secondary Energy Sources

Secondary energy sources are products of human technology generated from primary energy sources. The most common secondary energy source is **electricity**.

Form of Energy	Primary Energy Source	Transformation to Secondary Energy Source
mechanical	wind	windmill turns an electricity-generating turbine
chemical	peat	burns to heat water to make steam to turn a turbine
thermal	geothermal heat	well brings superheated water to surface to turn turbine
radiant	sunlight	photovoltaic cells generate current
nuclear	atomic nuclei	reactor heats water into steam to turn turbines

Electrical energy is useful in many ways, but there are no known, easily usable primary sources of electricity on earth. Lightning is a primary source of electricity, but it is highly unpredictable and cannot currently be used to power machines.

We use many different primary energy sources to generate electricity, which is then used to power machines that do useful work.

For example, coal, a primary energy source, is often burned in power plants to create electricity. The chemical energy from burning the coal is converted to thermal energy to boil water to make steam, which turns turbines, which spin electrical generators (figure 1-3-13).

It is hard for people in the United States to imagine life without ready access to electricity in houses, offices, factories and public places. But many rural areas were "electrified" only in the last few decades, and some people still choose to live in remote areas "off the **grid**" of electric power distribution. In many developing countries, electricity is still a luxury.

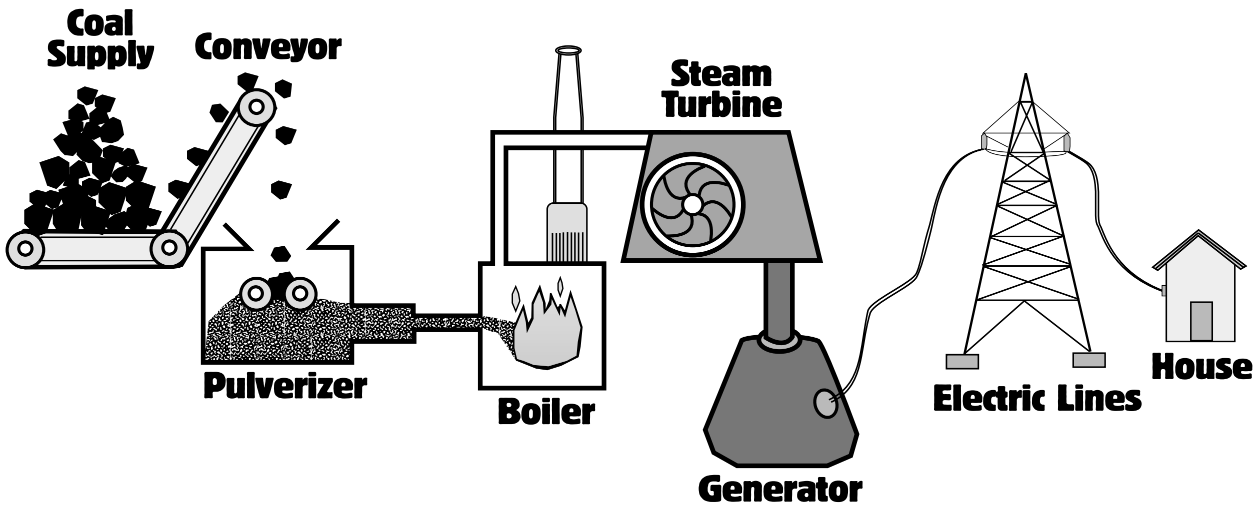


Figure 1-3-13 Steps in coal-powered electricity production
The coal is ground to a powder for more efficient combustion before it is burned to heat a boiler. The resulting steam is under pressure, so when released it has enough velocity to turn a turbine. The rotating turbine powers a generator. In the generator, magnets spin inside a wire coil to produce electricity. The current is then transmitted through wires to users.

Often electricity is more convenient to use than a primary energy source. When we use electricity to power a device, it is clean, quiet, and is supplied continuously on demand. However, producing electricity from a primary energy source such as coal is complex. Some energy is lost, some pollution is created and the process is often noisy. The amount of electricity created is also limited to less than the amount of the primary energy source available.

Electricity travels great distances as it moves from the generator to your home. First, the generating plant sends out electricity to a transformer. The **transformer** increases the force (voltage) of the electricity to hundreds of thousands of volts, depending on how far it must travel and how much must be delivered. Transmission lines carry the electricity long distances from the transformer.

Along this path, substation transformers reduce the voltage, usually to about 12,000 volts, for use by local areas. Distribution lines, which can be above or below the ground, then carry the electricity from substations' transformers to local neighborhoods. A third transformer found in the neighborhood reduces the voltage even further, to 120 or 240 volts. Now the electricity is ready for use.

Electricity can power lights, appliances, industrial processes, heating, cooking and air conditioning. It also has many other uses, such as transportation. Many cities use electricity for public transportation, like trains and subways. In these cases, electric current can be transmitted to the vehicle through special rails or another part of the track. Some cities also use electric buses or trolleys that receive current through a sliding connection to an overhead power line.

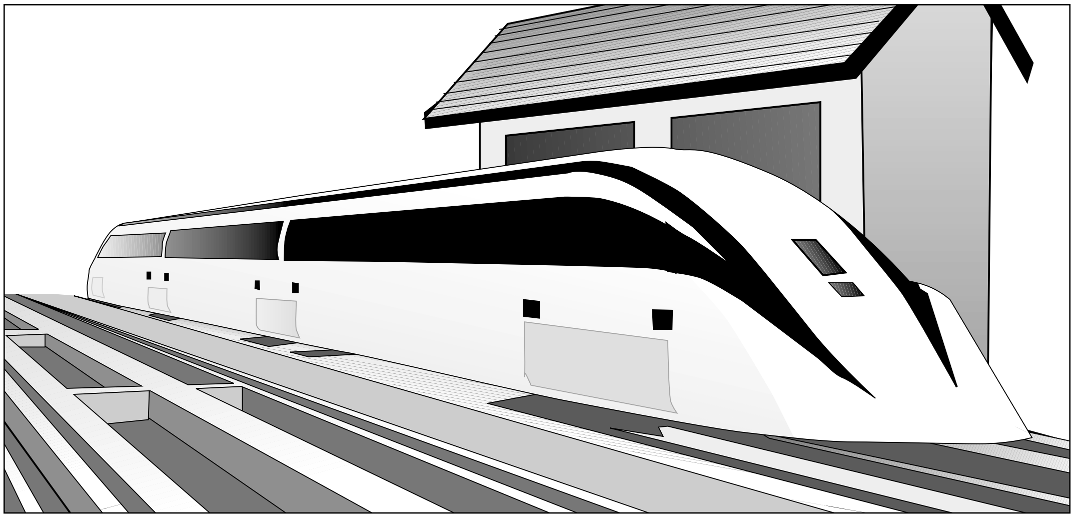


Figure 1-3-14 Maglev vehicle

Several countries are experimenting with trains without wheels. This technology, called **maglev** (for "magnetic levitation"), operates trains using a system of giant magnets and electricity. Japan built two maglev lines, the first in the 1960's and the second in 1996. The second maglev train that Japan built goes 344 mph or 550 km/h. Germany also has plans for a maglev rail line that will link Berlin with Hamburg in 2005. The U.S. and Britain have also tested the maglev train, but have no working models at this time.

Unlike these fixed-route trains, other **electric vehicles** run on electricity stored aboard the vehicle in batteries. They are not limited by a connection to a wire or electrified rail. They have several advantages, including zero emissions from the vehicle itself and quiet operation. Research is ongoing to increase the vehicles' range and lower batteries' weight, cost and size.

Figure 1-3-15 A hybrid vehicle

A promising option is the **hybrid vehicle** – one that runs on electricity and a clean (usually "alternative") fuel. Another technology under development is the fuel-cell vehicle, which produces electricity from hydrogen rather than storing it on board in a battery. See Unit 3, Section 3*: Fueling the Future.*

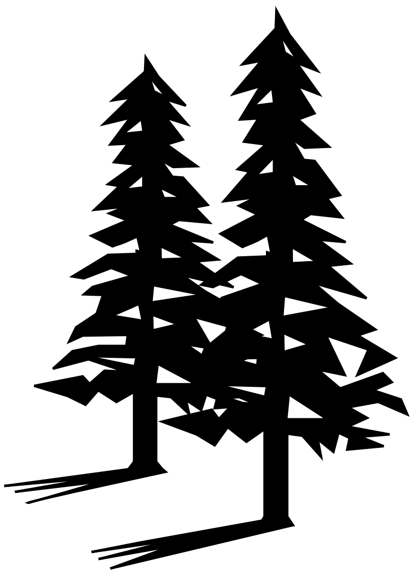


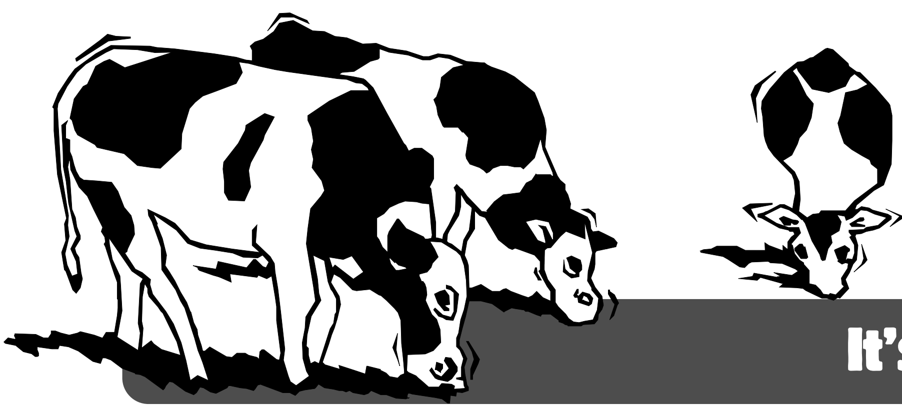
Figure 1-3-16 *Wood was once a conventional fuel in this country but is now considered an alternative fuel, because other fuels are now emphasized as energy sources.*

Alternative Energy Sources

"Alternative to what?" you might ask. The terms "alternative energy" and "alternative fuels" are common in the news media today. But what do they mean?

Generally, an **alternative energy source**, fuel or non-fuel, is one not commonly associated with a particular use. For example, windmills have been used for hundreds of years for mechanical power, such as grinding grain or pumping water, so the wind can be seen as a **conventional energy source** for those jobs. But wind power is considered an alternative energy source for generating electricity, because this is an application created only in the last few decades.

Natural gas is a conventional fuel for heating homes. However, it is considered an alternative fuel for powering vehicles, because that is a relatively new and little-used application for the fuel, and it requires new technology to make it work.



It's Been Dung Before

What is conventional and what is alternative also varies with time and culture. When kerosene was introduced, it was an alternative fuel for lamps, which conventionally burned whale oil. Today, we would certainly consider animal fat such as whale oil an alternative, rather than a conventional, fuel. In some countries, dried cattle dung is the most common fuel for cooking and heating. In industrialized countries, however, manure and other natural waste products are known as "biomass" and labeled alternative energy sources.

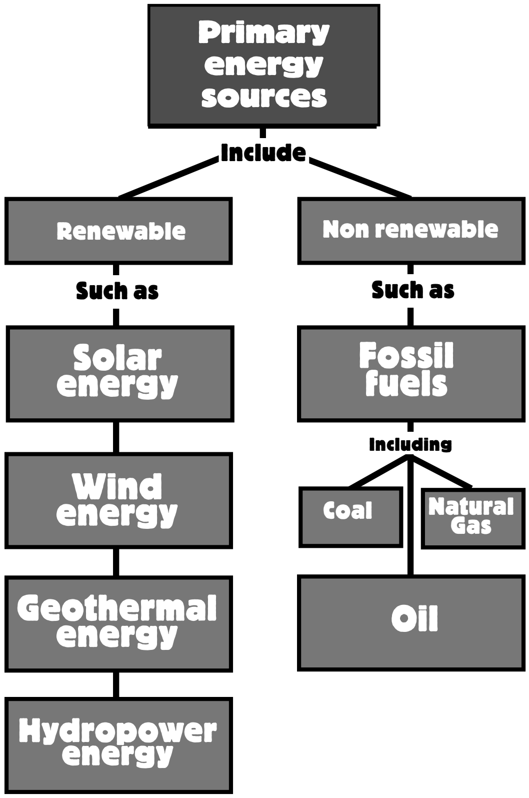


Figure 1-3-17
A concept map of energy resources

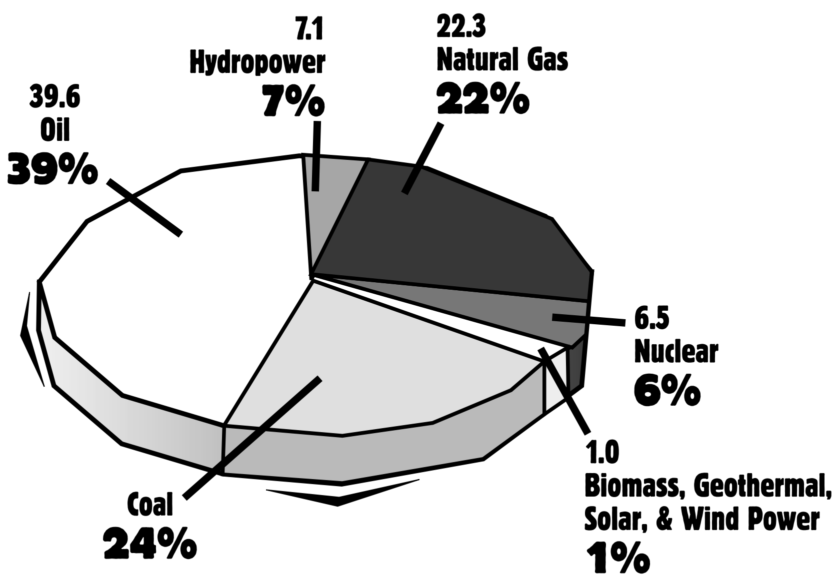


Figure 1-3-18 Sources of world energy, 1998

Source: U.S. Department of Energy

Energy Sources Resource List

www.iclei.org/efacts
Energy Educators of Ontario, Canada
Energy Fact Sheets describing past, present, and future use of energy, the advantages and disadvantages of individual energy sources, and the potential for using alternatives.

www.lcra.org
Lower Colorado River Authority, Texas
Information about using dams to generate electricity, control flooding, and conserve water.

www.infinitepower.com
Texas State Energy Conservation Office
Fact sheets on renewable energy for the general public as well as resources for classrooms and teachers.

www.eren.doe.gov
Energy Efficiency and Renewable Energy Network, U.S. Department of Energy
Comprehensive resource for energy-efficiency and renewable-energy information. More than 600 links, including educational materials and resources for children.

http://solstice.crest.org
Renewable Energy Policy Project/Center for Renewable Energy and Sustainable Technology, Washington, D.C.
Perspectives on current issues related to renewable energy and energy efficiency.

www.energy.ca.gov/education
California Energy Commission
Energy Quest site for children includes information on nuclear energy, science projects, renewable energy, art contests, puzzles, and individual scientists.

www.ece.utep.edu/Research/Energy/Pond/pond.html
University of Texas at El Paso, Salinity-Gradient Solar Technology Consortium
Describes salinity-gradient solar technologies, applications and the El Paso Solar Pond Project.

www.nrel.gov
National Renewable Energy Laboratory, U. S. Department of Energy
Renewable-energy technologies, research, applications, data and documents.

http://powerweb.lerc.nasa.gov/pvsee/programs/solarmoon.html
National Aeronautics and Space Administration
Describes past, present and future uses of photovoltaic power in the U.S. space program, including artists' conceptions of how photovoltaic cells could work on the moon and photovoltaic/regenerative fuel cell power systems for a lunar observatory.

www.tva.gov/heritage/hert_history.htm
Tennessee Valley Authority
The story of 12 hydroelectric power projects in the 1940s.

www.awea.org/projects
American Wind Energy Association, Washington, D.C.
Lists current and projected wind energy projects across the U.S.